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R.P.H. Chang
Jennifer Moncel, Editor

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Materials Research Institute, Northwestern University
2145 N. Sheridan Road, Room K111
Evanston, IL 60208

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13. ABSTRACT (Maximum 200 words)

The Pan-American Advanced Studies Institute (PASI) on Materials for Energy Conversion and Environmental Protection was held October 20-29, 2003 in Rio de Janeiro, Brazil. The event welcomed twenty distinguished lecturers and forty graduate and post-doctoral students, half from the US (including Puerto Rico) and half from outside the US (Argentina, Bolivia, Brazil, Canada, Chile, Mexico, Peru, Panama, and Venezuela.) Eight Pan-American student research groups were formed, each with a clearly defined plan to perform collaborative research on a topic related to Fuel Cells and Catalysis for Emissions Control.

The innovative program maximized interactive learning. Students were assigned into international teams of five, each led by a US co-leader and a Pan-American co-leader. Teams made contact before the PASI to identify potential research topics based on their common interests. Lecturers from industry, academia, and government mentored the students, helping them set goals, make budgets, and plan effective use of facilities. One-hour technical and policy lectures were followed by 30 minute question- and-answer periods. Each afternoon, students met with lecturers during 90-minute roundtable discussions. Students made their presentations and received feedback regarding project feasibility, budget planning, challenges, and additional methods of approach. Students are currently seeking funding for their proposed collaborative research.

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Pan-American Advanced Studies Institute

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Executive Summary

The Pan-American Advanced Studies Institute (PASI) on Materials for Energy Conversion and Environmental Protection was held October 20-29, 2003 in Rio de Janeiro, Brazil. Co-sponsored by the National Science Foundation (NSF), the Department of Energy (DOE), and the Army Research Office (ARO), the event welcomed twenty distinguished lecturers and forty graduate and post-doctoral students. By nationality, participants represented Argentina, Bolivia, Brazil, Canada, Chile, Mexico, Peru, Panama, the United States (including Puerto Rico), and Venezuela. Technical sessions covered topics related to Fuel Cells and Catalysis for Emissions Control. Eight Pan-American student research groups were created, each with a Joint Collaborative Research Plan to perform collaborative research in these areas.

Participants: Lecturers came from industry, academia, and government. Advanced graduate and postgraduate students were recruited from the physical sciences and engineering fields, half from the US and the other half from outside the US. Students were assigned into international teams of five, each led by a US co-leader and a Pan-American co-leader.

Format: The innovative PASI program maximized interactive learning. Teams made initial contact before the PASI, and identified potential research topics based on their common interests. Once at the PASI, lecturers mentored the students, helping them set goals, make budgets, and plan effective use of facilities. Team research plans included: rationale and intellectual merit for proposed research, division of tasks, facilities sharing, unique team strengths, challenges inherent in the global project and possible solutions, projected applications and technology transfer strategies, budget and broader impact.

One-hour technical and policy lectures were followed by 30 minute question & answer periods. Each afternoon, students met with lecturers during 90-minute roundtable discussions. Students made their presentations and received feedback regarding project feasibility, budget planning, challenges, and additional methods of approach. The last 4 days of the PASI coincided with the opening of the second annual meeting of the Brazil Materials Research Society (Brazil-MRS), held at the same locale. PASI participants received complementary registration for this event and were encouraged to attend lectures and exhibits.

Outcomes: The main deliverables of the PASI were: (1) Advanced Technical Lectures (2) Improved global skill set for students (3) Eight Pan-American student research groups, each with a clearly defined Joint Collaborative Research Plan.

Evaluation: Student and lecturer feedback has been overwhelmingly favourable. Many students plan to continue their collaborations and implement their planned research. Lecturers were very pleased with the student projects and some even offered to look into internships, institutional funding and lab use to help the students implement their projects. Overall, both groups were very pleased with the prospects for fruitful collaborations.

Broader Impact: Plans are underway to help PASI students implement their research plans. Students also have the opportunity to develop the PASI website, hosted at Northwestern. It is hoped that this program can serve as an effective model for other educational and networking events around the world. To this end, three African scientists attended the PASI through an NSF supplement, with a view to establishing similar institutes in their regions.

Part 1: Introduction

The Pan-American Advanced Studies Institute (PASI) on Materials for Energy Conversion and Environmental Protection was held October 20-29, 2003 in Rio de Janeiro, Brazil. The event welcomed twenty distinguished lecturers and forty graduate and post-doctoral students. By nationality, PASI participants represented Argentina, Bolivia, Brazil, Canada, Chile, Mexico, Peru, Panama, the United States (including Puerto Rico), and Venezuela. (See Appendix 1 for a list of attendees.)

The primary goal of the PASI was to disseminate advanced scientific and engineering knowledge and stimulate training and cooperation among Pan-American researchers in two of the most crucial branches of Sustainable Development: Energy Management and Environmental Protection. The PASI successfully created eight pan-American student research groups, each of which produced a detailed plan for collaborative research in these areas.

PASI Sponsors

PASI was co-sponsored by the National Science Foundation (NSF), the U.S. Department of Energy (DOE), and the U.S. Army Research Office (ARO). Thanks to their generous support, students and lecturers from throughout the Americas received full travel and lodging support during the entire event.

PASI Theme

The PASI theme was Materials for Energy Conversion and Environmental Protection. Technical sessions covered topics related to Fuel Cells (Energy Conversion) and Catalytic Materials for Emissions Control (Environmental Protection), including:

- Fuel cell principles, design, and applications
- Fuel cell systems for distributed energy generation and portable devices
- Catalytic materials for hydrogen gas generation
- Carbon and metallic materials for hydrogen storage
- Catalyst structure and surface chemistry
- Catalytic materials for environmental protection and emissions reduction
- Pan-American Environmental and Energy policy
- Funding resource management

This theme was especially timely in the western hemisphere where energy and environment issues top the agendas of national governments, including the United States and Brazil, where air pollution levels in its largest cities are among the worst in the world, as indicated by regular "brown outs." US-Pan-American collaborations are now being called for in these and other research areas.

Part 2: Pre-event Coordination

The PASI was co-organized by Prof. R.P.H. Chang, Director of the Materials Research Institute at Northwestern University and Prof. Guillermo Solorzano, founding president of the Brazilian Society for Materials Research (Brazil-MRS). Please see Appendix 2 for information on the organizers.

Student Recruiting

The PASI recruited advanced graduate and postgraduate students in the physical sciences and engineering fields. Several junior researchers, particularly from South American countries, were also accepted. Preference was given to students whose thesis work and/or demonstrated research interests were directly related to the theme of energy conversion and environmental protection. A PASI website http://www.materialsworld.net/PASI/ was developed to provide information and serve as a recruiting platform. Students downloaded application forms and submitted them with two letters of recommendation, one from their thesis advisor. (See Appendix 3 for recruiting materials)

Informational e-mails and posters were sent to North and South American universities graduate programs in Chemical Engineering, Environmental Engineering, Materials Science, and the like. Wherever possible, emails were sent directly to the appropriate department offices and graduate advisors for dissemination to students. Student chapters of professional and technical societies were contacted, and announcements were posted in publications such as the *MRS Bulletin*. To ensure diversity among US students, organizers contacted science and engineering departments at US Minority Institutions and the student chapters of the National Society of Black Engineers (NSBE), the Society of Hispanic Professional Engineers (SHPE), the Society of Women Engineers (SWE), among others. To help ensure geographic diversity, recruiting materials were distributed in English, Spanish and Portuguese, and several Canadian universities were also contacted in French.

Selections were made based on student evaluations by invited lecturers and members of the organizing committee. Selection criteria included research experience, supporting letters, and the ability to comprehend advanced lectures. In accordance with NSF guidelines, an equal number of US and Pan-American students were selected as participants. This 1:1 ratio allowed for unique opportunities for participants to grow in cultural understanding and learn more about research and education in other countries. There were a total of nine women, most from South America.

Student Participation

Sustainable research collaborations among students and a new set of funding proposals to Pan-American agencies were important anticipated outcomes of the PASI. To this end, the PASI was based on student team projects – Joint Collaborative Research Plans based on common student interests. The research plans were the students' first step toward obtaining funding to carry out collaborative research. Lecturers mentored the students, helping them set goals, plan effective use of facilities, and present their research plans for funding. Students presented their research plans for evaluation and constructive feedback from lecturers. Team research plans included: rationale and intellectual merit for proposed research, division of tasks, facilities sharing, unique team strengths, challenges inherent in the global project and possible solutions, projected applications and technology transfer strategies, budget and broader impact. (See Appendix 4 for Student Project Guidelines)

Student Team Assignments

Students were assigned into teams of five, each led by a US co-leader and a Pan-American co-leader. Team assignments were made based on area of research and level of study, with careful attention to ensuring geographic, cultural, and gender diversity. A sample team is given below:

Team Number	Country	Gender	School	Research (Thesis)
1	US	Male	University of Delaware	High throughput catalysis: testing of deNOx and NH3 decomposition catalysts under transient and steady state conditions
1	Mexico	Male	Universidad Nacional Autonoma de Mexico	Photocatalytic applications of titanium dioxide thin films prepared by spray pyrolysis and D.C. reactive sputtering methods.
1	Venezuela	Female	Universidad Central de Venezuela	Materials as Gas Sensors: Correlation between gas sensors properties and catalytic activities
1 Leader	US	Male	University of New Mexico	Coating Microchannels with Catalytic Slurry for Methanol Reforming
1 Leader	Bolivia (Chile)	Male	University of Chile	Formation and study of nanotubes to derivatives of metal transition

Student Preparation

About a month before the event, project guidelines, lecture abstracts, and suggested readings were posted on the website and students were encouraged to make initial contact with their team members to begin working on their projects.

Lecturers:

PASI lecturers came from industry, academia, and government. Advisory Board members were asked to recommend lecturers with expertise in fuel cells and environmental catalysis. Lecturers were invited to present 1-hour lectures and serve as mentors to the student groups. (See Appendix 5 for a list of PASI lecturers).

Part 3: PASI Program

Program Highlights

The innovative PASI program maximized interactive learning. Highlights included:

- ☐ Technical and policy lectures
- ☐ Question and answer periods after each lecture
- ☐ Roundtable planning meetings where student teams worked on their projects, assisted by lecturers
- ☐ Informal interactions over coffee and meals
- ☐ Group tour of local industrial laboratory
- ☐ Student project presentations
- ☐ Lecturer feedback

One-hour lectures were followed by 30-minute question & answer periods. Each afternoon, students received mentoring from lecturers during 90-minute roundtable discussions. In the middle of the program, participants visited the Petrobras CENPES laboratory. After making their presentations, students received feedback from lecturers regarding project feasibility, budget planning, challenges and additional methods of approach.

The last 4 days of the PASI coincided with the opening of the second annual meeting of the Brazil Materials Research Society (Brazil-MRS) which was held at the same locale. PASI participants received complementary registration for this event and were encouraged to attend lectures, exhibits, and the main banquet (See Appendix 6 for the Program Agenda).

Part 4: PASI Outcomes

The innovative PASI program structure went far beyond the scope of a traditional conference to provide students with unique opportunities for interactive learning and hands-on experience. The main deliverables of the PASI were:

- Advanced Technical Lectures– Expert lecturers from industry, government and academia shared advanced knowledge in fuel cells, emission control processes, and environmental catalysis. Most PASI lectures have been posted on the website for public viewing.

- Improved skill set for students: students built key global leadership skills and learned how to determine research priorities based on current research, government policies and potential future trends.

- Eight pan-American student research groups, each with a clearly defined Joint Collaborative Research Plan. It is hoped that these student plans will eventually lead to successful Pan-American research collaborations.

Joint Collaborative Research Plans

Student presentations were met with much enthusiasm. We feel that they are worthy of interest because they are the result of common interests, interdisciplinary planning, and expert mentoring. Student Research topics were as follows:

Team 1: Novel Perovskite Based Catalysts

Team 2: Development of new ethanol steam reforming catalyst

Team 3: Nano-Porous Alumina for Fuel Cell Enhancement

Team 4: Block Copolymer Assisted Self-Assembly Of Nanoporous $(La_{0.6}Sr_{0.4})(Fe_{0.8}Co_{0.2})O_{3-\delta}$ Cathodes For SOFC

Team 5: Studies of SOFC Electrode Materials Using a Single Atmosphere Fuel Cell

Team 6: Medium Temperature Proton Exchange Fuel Cells Using Composite Membranes

Team 7: Movement toward the hydrogen economy based on fuel derived from biomass utilized in a reduced cost PEM fuel cell

Team 8: Integrated Micro-Reformer and Separator for Portable Production of High Purity H_2

In the course of developing these projects, students built valuable research, management and leadership skills including: international team building; project development; intercultural communication; and formulating strategies and budgets for research involving multiple institutions. Presentations and text summaries have been posted on the PASI website for public viewing. (See Appendix 7 for a sample student research plan)

Program Evaluation

Evaluation forms were distributed to students and lecturers on site and posted on the website (See Appendix 8). Both student and lecturer feedback has been overwhelmingly favorable. Based on evaluations received to date, 100% of students and lecturers agreed that the PASI structure was conducive to information exchange and research collaborations, and 84% of students definitely plan to continue to research collaborations begun at PASI, and most of the remaining 16% said their continuation was contingent upon available funding and institutional support.

Student Feedback

Here are some of the things students most appreciated about the experience:

"The PASI recruited very high level people-I was very impressed. Thank you!"

"The [group project] was very helpful in dealing with different people…a very useful real life exercise."

"The PASI presented huge challenges for me as my first experience with international team building."

"Interactions with my fellow team members. The group brought fantastic skills, knowledge, [and the] desire to interact on effective projects."

Lecturer Feedback

Lecturers appreciated the format and found the level of students quite good. Having worked as mentors to the student groups, they also appreciated the composition of the teams and remarked that they were well balanced, motivated and worked well together. They were very pleased with the student projects and some even offered to look into internships and institutional funding and lab use to help the students implement their projects. Overall, they were very pleased with the prospects for fruitful collaborations. Here are a few of their comments:

"Excellent format-I made some contacts with other lecturers that were useful."

"The Q&A sessions were relaxed and intelligent"

"The students were very well selected and demonstrated good performance and capacity"

"I enjoyed the interaction with the [student] groups. They were receptive to new ideas and very appreciative of our advice."

"The roundtable discussions were very productive-I had the opportunity to interact more strongly with a few of the groups."

Suggestions for Improvement

Suggestions for improvement included: organizing morning and evening sessions with free afternoons, giving student bios to lecturers and lecture slides to students before the meeting, offering better computer and internet access, presenting subject overviews earlier in the program, making English a stronger criterion for acceptance, and creating funding opportunities for PASI participants.

Part 5: Future Plans

In keeping with our goal of creating sustainable research collaborations among young Pan-American scientists, plans are now underway to help PASI students implement their research plans. Our current efforts to support cooperation among PASI Scholars are outlined below.

Project Development Assistance

R.P.H. Chang is requesting additional funding to support ongoing mentoring and other assistance for students as they refine their projects and submit proposals to Pan-American agencies. It is our hope that numerous new research proposals will result. This outcome will be in accordance with current efforts by US and Pan-American agencies to promote research collaborations. For example, US-Pan-American Implementation Meetings have taken place in 2002 and 2003, to implement agreements for cooperative activities in materials sciences and over 25 joint research collaborations have already received funding.

Internet-based Activities

We are also providing the PASI students the opportunity to develop the PASI website, which is being hosted at Northwestern University.

Model for other events

In their original proposal to NSF, PASI organizers voiced the hope that similar institutes might be created in other parts of the world. As part of this effort, the organizers received an NSF supplement to bring African scientists to attend and observe the PASI, with a view to establishing similar institutes in Africa. The following three African researchers and network leaders attended the PASI: Prof. AC Beye of Senegal, Prof. M. Sassi of Tunisia, and Prof. J. Tesha of Tanzania.

Appendix 1: Attendance List

First Name	Last Name	Role	Country	Institution
Mariela	Alvarez	Student	Chile	Universidad de Chile Santiago
John	Amphlett	Lecturer	Canada	Royal Military College
Charles	Arvin	Student	US	Notre Dame University
Fernando	Baratelli	Lecturer	Brazil	Petrobras
Mariella	Berrocal	Student	Peru (Brazil)	Universidade Federale do Rio
Aboubaker C.	Beye	Observer	Senegal	Department of Physics, IUCAD, Dakar
Jaime	Bravo	Student	US	University of New Mexico
Carlos	Cabrera	Lecturer	US	University of Puerto Rico
Ernesto	Calvo	Lecturer	Argentina	Universidad de Buenos Aires
Facundo	Castro	Student	Argentina	Instituto Balseiro, Universidad National de Cuyo
R.P.H.	Chang	Organizer	US	Northwestern University
Christopher	Chervin	Student	US	University of California-Davis
Virginia	Ciminelli	Lecturer	Brazil	UFMG
J. Fernando	Contadini	Observer	Brazil	Petrobras (CENPES)
Maria C.	Curet-Arana	Student	US (Puerto Rico)	Northwestern University
Robert	Davis	Lecturer	US	University of Virginia
Patricia	Dias	Student	Brazil	University of Sao Paulo
Mildred	Dresselhaus	Lecturer	US	Massachusetts Institute of Technology
James	Dumesic	Lecturer	US	University of Wisconsin
Robert	Farrauto	Lecturer	US	Engelhard Corporation
Fabio	Fonseca	Student	Brazil	Nuclear and Energy Research Institute
Wesley	Francillon	Student	US	Stonybrook University
Carlos B. W.	Garcia	Student	US	Cornell University

First Name	Last Name	Role	Country	Institution
Mery Cecilia	Gomez Marroquin	Student	Peru (Brazil)	Pontificia Universidade Catolica do Rio de Janeiro
Pedro A.	Gonzalez Beerman	Student	Panama (US)	Western Michigan University
Francisco J.	Gracia	Student	Chile (US)	University of Notre Dame
Claudia Elizabeth	Gutierrez Wing	Student	Mexico (US)	University of Texas - Austin
Raed	Hashaikeh	Student	Canada	McGill University
Reed	Hendershot	Student	US	University of Deleware
George	Huber	Student	US	University of Wisconsin
Kevin	Hurysz	Student	US	Georgia Technical Institute
Stephen	Jesse	Student	US	University of Tennesee
Jason	Kenney	Student	US	University of Texas - Austin
Kevin	Krantz	Student	US	University of California-Los Angeles
Vladimir	Lavayen	Student	Bolivia (Chile)	University of Chile
Felipe	Lineo	Student	Chile	Universidad de Chile
Carlos	Magana	Student	Mexico	Universidad Nacional Autonoma de Mexico
Arturo	Martinez	Student	Mexico	Universidad Nacional Autonoma de Mexico
Paul H.	Matter	Student	US	Ohio State University
Dennis	Miller	Lecturer	US	Michigan State University
Nguyen	Minh	Lecturer	US	General Electric Hybrid Power Generation Systems
Jennifer	Moncel	Organizer	US	Northwestern University
Claudia	Neyertz	Student	Argentina	Universidad Nacional de Cuyo
Ryan	O'Hayre	Student	US	Stanford University
Victor	Poblete	Student	Chile	University of Chile
Fernando	Prado	Student	Argentina	Materials Caracterization Group-Centro Atomico Bariloche
Raul	Quijada	Lecturer	Chile	Universidad de Chile

First Name	Last Name	Role	Country	Institution
Jackeline	Quinones	Student	Venezuela	Universidad Central de Venezuela
Bill	Rauch	Student	US	Georgia Technical Institute
Fabio	Ribeiro	Lecturer	Brazil	Purdue University
Omar	Roshdy	Student	US	Massachusetts Institute of Technology
Mohamed	Sassi	Observer	Tunisia	ENIM
Martin	Schmal	Lecturer	Brazil	COPPE/UFRJ
Brent	Shanks	Lecturer	US	Iowa State University
Subhash	Singhal	Lecturer	US	Pacific Northwest National Laboratory
Guillermo	Solorzano	Organizer	Brazil	Brazil MRS
Susan	Stagg-Williams	Lecturer	US	University of Kansas
Joseph V.	Tesha	Observer	Tanzania	University of Dar es Salaam
Juliano	Toniolo	Student	Brazil	Federal University of Rio Grande do Sul
Maria Helena	Troise Frank	Observer	Brazil	Petrobras (CENPES)
Paulo Emilio	Valadao de Miranda	Lecturer	Brazil	COPPE/UFRJ
Marvin	Vasquez	Student	US	Stonybrook University
Pedro	Villalobos	Student	Brazil	COPPE/Universidade Federal do Rio de Janeiro
Roberto	Villas Boas	Lecturer	Brazil	IMMAC
Kimberly	Wain	Student	US	Pennsylvania State University
Ian	Wheeldon	Student	Canada	Royal Military College
Wayne	Worrell	Lecturer	US	University of Pennsylvania
Miguel Jose	Yacaman	Lecturer	Mexico (US)	University of Texas
Daniel	Zanetti del Florio	Student	Brazil	University of Sao Paulo

Appendix 2: Organizing and Advisory Committees

Organizers

R.P.H. Chang is the Director of the Materials Research Institute and a professor in the Materials Science and Engineering Department at Northwestern University. He is also involved in the development of web-based learning in materials science for pre-college students. During the past two decades, he has been engaged in serving the global materials research community. He is the founding president of the International Union of the Materials Research Societies, which now has 12 members around the world. Over the last 8 years he has been helping the international materials community to define ways to work together through a series of international workshops co-sponsored by the NSF. (See the reports posted at http://www.iumrs.org). An outcome of this effort is the establishment of a Materials World Net, the planning of which is now underway.

Guillermo Solorzano has been a professor of materials science and engineering at the Catholic University of Rio de Janeiro (PUC-RIO) since 1984. He received his S.B. degree from PUC-RIO in metallurgical engineering in 1975 and his M.Sc. degree in materials science in 1977 from the same institution. In 1983 he was awarded his Ph.D. in materials science from McMaster University (Canada). Dr. Solorzano was a chairperson for the NSF-sponsored *Workshop to Advance Pan American Collaboration* in 1998. He is the founding president of the Brazilian Society for Materials Research and the president of the Inter-American Committee of Societies for Electron Microscopy (CIASEM).

Organizing Committee members:

Wolfgang Sachtler is a former V.N. Ipatieff Professor at Northwestern University. He received his Ph D from the University of Technology in Braunschweig, Germany. Significant awards include: Member Royal Netherlands Academy of Sciences; Petroleum Chemistry Award from the American Chemical Society; E.V. Murphree Award from the American Chemical Society; and, the Robert L. Burwell Jr. Award in Catalysis. Dr. Sachtler is advising the PI on catalysis and environmental protection.

Roberto JJ Williams is professor at the National University of Mar del Plata, (Argentina) and a member of the National Research Council (CONICET), Argentina. The author of two books and 150 journal articles and book chapters, he is also a member of the American Chemical Society and the Polymer Network Group. His main areas of interest are: thermosetting polymers, thermoset/thermoplastic blends, polymer dispersed liquid crystals, and organic / inorganic hybrid materials based on functionalized polysilsesquioxanes.

Subhash Singhal is a Battelle Fellow and Director of Fuel Cells at the Pacific Northwest National Laboratory. Dr. Singhal joined the Energy Science and Technology Division at PNNL in April 2000 after having worked at Siemens Westinghouse Power Corporation for over 29 years. He has served on many advisory panels including those of the National Materials Advisory Board of the National Research Council, National Science Foundation, Materials Properties Council, U.S. Department of Energy, NATO Advanced Study Institutes, United Nations Development Programme (UNDP), and the United Nations Industrial Development Organization (UNIDO).

International Advisory Committee members:

Harold Kung is a Professor of Chemical Engineering at Northwestern University, where he also received his PhD. Kung's research interests are focused on kinetics and catalysis. Dr. Kung has been the recipient of the Herman Pines Award of the Chicago Catalysis Club and the Paul H. Emmett Award from the Catalysis Society. He was the Chair of the Gordon Research Conference on Catalysis, a John McClanahan Henske Distinguished Lecturer at Yale University, and the Olaf A. Hougen Visiting Professor at the University of Wisconsin-Madison. He is a Fellow of Japan Society for the Promotion of Science and Editor of *Applied Catalysis A: General*.

Fernando Lund is the Director of the Center for Advanced Interdisciplinary Research in Materials (CIMAT) in Chile and is the principal investigator of the materials theory group. Dr. Lund received his Ph. D. in Physics from Princeton University in 1975.He has been on the faculty of the physics department at the Universidad de Chile since 1978, and a full professor since 1985. Dr. Lund has been the principal investigator of six Fondo Nacional de Desarrollo Científico y Tecnológico (FONDECYT) projects and one major collaborative project funded by the European Economic Community. He was the President of the Chilean Physical Society (1981-1982), and has been a member of the Chilean Academy of Sciences since 1992. Other honors include the Cátedra Presidencial en Ciencias (1995-1998), Medalla Rectoral, Universidad de Chile (1996), and the National Science Prize of Chile 2001.

Caribay Urbina is a researcher and Professor at the Center of Electro-Microscopy. She has been a member of the CEM since 1984, when she completed her Ph.D. under the direction of Dr. Mitsuo Ogura. Prof. Urbina is a specialist in high-resolution analytic electro-microscopy and his areas of research include catalysis, polymers, and nanoparticles.

STUDENT APPLICATION

Pan-American Advanced Studies Institute (PASI) on

Materials for Energy Conversion and Environmental Protection

Rio de Janeiro, Brazil, October 20- 29, 2003

Co-sponsored by the US Department of Energy, the National Science Foundation, and the US Army Research Office

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Please return this application and two letters of recommendation (one from your advisor) to:

Program Coordinator, PASI Program, Materials Research Institute, Northwestern University
2145 Sheridan Road, K111, Evanston, IL 60208

Phone: 847-467-7613 Fax: 847-467-6727 Email: mri@northwestern.edu

APPLICATION MATERIALS MUST BE RECEIVED BY JULY 30, 2003.

CONTACT

S.S Number ______________ **Name**____

Permanent (Mailing) Address ____

City ____________________ **State**_______ **Postal Code** _________**Country**________

Telephone_______________________ **E-mail** __________________________________

EDUCATION

Current College/University ____

Current Academic Year __________________ **Grade Point Average/Scale** _______________

Highest Degree Earned __________________ **Thesis Completion Date** ________________

Thesis Title/ Research Topic

____

How does the theme of Energy Conversion and Environmental Protection apply to your thesis work and/or research interests?

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DEMOGRAPHIC INFORMATION (Please check all that apply)

This demographic data allows our sponsors to gauge whether the programs they support are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research opportunities. Submission of this information is voluntary and is not a precondition of admission.

Gender: □ Male □ Female

Ethnicity: □ Hispanic or Latino □ Not Hispanic or Latino

Race (Select one or more): □ Native Hawaiian or Other Pacific Islander □ Asian
□ Black or African American □ White
□ American Indian or Alaska Native

Disability Status: □ Hearing Impairment □ Other
□ Visual Impairment □ None
□ Mobility/Orthopedic Impairment

Country of Citizenship:____________________ **Country of Residence:** ________________________

Applicant Signature ____________________________________ **Date** __________________________

STUDENT LETTER OF RECOMMENDATION

Pan-American Advanced Studies Institute (PASI) on

Materials for Energy Conversion and Environmental Protection

Rio de Janeiro, Brazil, October 20- 29, 2003

Co-sponsored by the US Department of Energy, the National Science Foundation, and the US Army Research Office

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Please return two (2) letters of recommendation using this form, and a completed application to:

Program Coordinator, PASI Program, Materials Research Institute, Northwestern University
2145 Sheridan Road, K111, Evanston, IL 60208
Phone: 847-467-7613 Fax: 847-467-6727 Email: mri@northwestern.edu
Website: http://www.materialsworld.net/PASI/

APPLICATION MATERIALS MUST BE RECEIVED BY JULY 30, 2003
ONE LETTER OF RECOMMENDATION MUST COME FROM YOUR ADVISOR

How long have you known the student?

In what capacity do you know the student?

How well does the student work in the collaborative mode?

Is the student a leader type?

Is the student a serious researcher?

Other comments:

Your name, title, affiliation(s)

Signature ____ **Date** ___________________________

Pan-American Advanced Studies Institute (PASI) on

Materials for
Energy Conversion and Environmental Protection

Rio de Janeiro, Brazil
October 20 ~ 29, 2003

Full Financial Support Available!!!
Grad students and postdocs are strongly encouraged to Apply Now!

Download an application from our website: http://www.materialsworld.net/PASI/
Two letters of recommendation (one from your advisor) are required.
Deadline: July 30, 2003

Theme:
Fuel Cells will be the focus of our Energy Conversion program and **Emissions Control** will be at the heart of our Environmental Protection program.

Topics:
- Policy-making and funding resource management
- Fuel cell principles, design, and applications
- Catalytic materials for hydrogen gas generation
- Carbon and metallic materials for hydrogen storage
- Fuel cell systems for distributed energy generation and portable devices
- Catalyst structure and surface chemistry
- Catalytic materials for environmental protection and emissions reduction

Program Highlights:
- Pan American Lecturers from academia, government and industry
- Policy and Technical sessions
- International networking
- Panel and Roundtable Discussions
- Students submit Joint Research Proposals
- Interdisciplinary, intercultural Working Groups

Student Participation:
The PASI will **generate real partnerships** among young Pan-American scientists and give them the tools and direction needed to sustain their future collaborations. Students will emerge with **hands-on experience** initiating and developing Pan-American research collaborations. **Full student financial support is available through our sponsors!**

Co-organized by the Materials Research Institute (Northwestern University) and the Materials Research Society of Brazil.

Appendix 4: Project Guidelines (distributed to students)

The PASI aims to create sustainable collaborations among Pan-American researchers and engineers. Students are therefore invited to join a Pan-American team to establish a viable research collaboration project related to “Materials for Energy Conversion and Environmental Protection” Each team will be asked to make a **Joint Collaborative Research Plan** describing their project. Team assignments can be found at http://www.materialsworld.net/PASI/.

The Joint Collaborative Research Plan should address the following points:

- ☐ What is the topic of your joint research?
- ☐ Rationale – Why is this topic significant? What problems will it address?
- ☐ How will the research be performed? – Who will do what? Which facilities will be used? How will the unique strengths and capabilities of your team support your research?
- ☐ What will be the outcome of the project? – What new scientific understanding and new applications will result?
- ☐ Estimated cost and duration of the project?
- ☐ Given that your team members will be working in different locations, discuss the challenges and issues involved (i.e. communication, data management, project implementation, etc…) and offer possible solutions.

Before the PASI, your team should:

- ☐ Discuss and identify the unique strengths and capabilities of your team (i.e. your combined technical knowledge and skills, special know-how, access to research and other facilities, advisors willing to provide assistance, etc…)
- ☐ Based on these unique strengths and capabilities, identify and plan to address a problem related to the PASI theme.
- ☐ Prepare for the lectures by reading abstracts and suggested reading materials on the website
- ☐ Discuss possible topics for the project – several possible topics are listed for your consideration on the website. Your team can choose one of these topics or just use them as a basis for group discussion.
- ☐ Read lecturer bios and consider which lecturers you might consult for your project.

At the PASI, your team should:

- ☐ During lectures and discussions, consider how the lecture topics might relate to your project ideas and enlarge upon them.
- ☐ During roundtable discussions, discuss your project with lecturers or fellow team members
- ☐ Network with lecturers to discuss your project during free time
- ☐ Present your Joint Collaborative Research Plan in a 30-minute PowerPoint presentation at the end of the PASI* See agenda for presentation schedule.
- ☐ Submit a written version of your Joint Collaborative Research Plan in Word format (2-3 pages)*

Appendix 5: Lecturers

John C. Amphlett (Royal Military College, Canada) heads the Department of Chemistry and Chemical Engineering at the Royal Military College of Canada. Prof. Amphlett's will lecture on fuel processing for fuel cell systems. For many fuel cell applications, especially in transportation, where the range between refueling needs to be reasonable, the hydrogen is likely to be stored on the vehicle in the form of a liquid hydrocarbon. Conversion of this hydrocarbon to hydrogen on board is thus an important step and this process will be the focus of Prof. Amphlett's lecture.

Fernando Baratelli Junior (Petrobras R,D&E Centre, Brazil) is a Chemical Engineer by USP and holds an MBA in Knowledge Management and Competitive Intelligence. Dr. Baratelli is a member of Superior Concil of ABEQ, a Brazilian Chemical Engineers Association and sits on the the Administrative Council of FUJB(José Bonifacio University Foundation, which is linked to UFRJ. He is currently Manager of Gas and Power R&D Group of CENPES, Petrobras R,D&E Centre. Dr. Baratelli has experience in Alcoholchemisty, Catalyst Development, Refining Process Development, and Product Development.

Ernesto Calvo (Universidad de Buenos Aires, Argentina) received his Chemistry First Degree at University of Buenos Aires (1975) and his PhD degree at La Plata University (1979) under the supervision of Prof. D.J. Schiffrin. From 1979-1982, he was a post-doc at Imperial College (London) and worked at Case Western Reserve University from 1983-84. Prof. Calvo is a professor of physical chemistry, head of the electrochemistry group, head of the inorganic chemistry department, and a member of the Instituto de Quimica-Fiscia de los Materiales, Medio Ambiente y Energia (INQUIMAE) executive committee. Since 1985, he has been a member of the Argentine Science Research Council (CONICET), and is part of the permanent research staff there. His research interests include chemically modified electrodes with biomolecules, enzyme electrodes, redox hydrogels and self-assembled layers, oxide electrodes, oxygen electro reduction.

Virginia Ciminelli (Universidade Federal de Minas Gerais, Brazil) is a professor in the Department of Metallurgical and Materials Engineering at the Universidade Federal de Minas Gerais, Belo Horizonte, Brazil. Prof. Ciminelli will speak on Materials Issues in Environmental Protection.

Carlos R. Cabrera (University of Puerto Rico, Rio Piedras) is Professor of Chemistry at the University of Puerto Rico, Rio Piedras. He received his Ph.D. from Cornell University, 1987 and was a Postdoctoral Research Associate at the University of Texas at Austin, 1987-88. He was a NASA Administrator's Fellow, Glenn Research Center, 2000-2001. Prof. Cabrera's research interests include: Electrochemistry and Materials Sciences: Direct Methanol Fuel Cells; Li Batteries; Nanostructured Surfaces; Sensors and Surface Analysis.

Robert Davis (University of Virginia) is an Associate Professor of Chemical Engineering at the University of Virginia. He received his B.S. ChE from Virginia Tech in 1985, his M.S. from Stanford University in 1987, and his Ph.D. from Stanford University in 1989. He is the recipient of the Award for Excellence in Teaching from Rhodman Scholars Program (2000), the NSF Young Investigator Award, the DuPont Young Professor Award, and the Union Carbide Innovation Recognition Award. Prof. Davis' research interests are heterogeneous catalysis, characterization of metal clusters, and reaction kinetics.

Mildred Dresselhaus (Massachusetts Institute of Technology) is one of twelve active Institute Professors at MIT. Her recent interests have been directed toward the study of the structure and properties of carbon nanotubes, and other novel forms of carbon, bismuth nanowires and low dimensional thermoelectric materials. Prof. Dresselhaus was sworn in August 2000 as the Director of the Office of Science at the United States Department of Energy and in January 2001 returned to MIT. Her positions include: Professor, MIT Department of Electrical Engineering and Computer Science 1968-present; Professor, MIT Department of Physics, 1983-present; President of the American

Physical Society, 1984; Institute Professor, 1985-present; Treasurer, US National Academy of Sciences, 1992-1996; President, American Association for the Advancement of Science, 1997-1998; Chairman of the Board, American Association for the Advancement of Science, 1998-1999.

James A. Dumesic (University of Wisconsin) is Steenbock Professor of Chemical Engineering. He received his M.S. and Ph.D. from Stanford University. His research interests include kinetics and catalysis, surface and solid-state chemistry, in situ catalyst studies. Prof. Dumesic's research group is currently working in the broad areas of heterogeneous catalysis and surface science.

Robert Farrauto (Engelhard Corporation) is a Research Fellow at the Corporate Research Laboratories of Engelhard in Iselin, New Jersey, an Adjunct Professor of Chemical Engineering at New Jersey Institute of Technology and is a leader in catalysis research and fuel cell-related catalysis research. Currently he is managing a research team investigating hydrogen production for fuel cells to be used for stationary and vehicular applications. Dr. Farrauto holds over 25 U.S. patents and has authored more than 60 journal articles. He has also co-authored one book on the fundamentals of industrial catalytic processes and another book on catalytic air pollution control. He is the North and South American editor of Applied Catalysis B: Environmental.

Denis J. Miller (Michigan State University) is Professor of Chemical Engineering. He received his Ph.D. in Chemical Engineering from the University of Florida in 1982. Prof. Miller's research interests include: Reaction engineering, catalysis, chemicals from renewable feedstocks, gasification and related thermochemical conversions, hydrogenation, and reactive separations.

Nguyen Minh (Honeywell, Inc.) holds a Ph.D., Chemical Engineering and is currently Manager, Fuel Cells at Honeywell Engines, Torrance, California. He leads the effort at Honeywell in the development of solid oxide and proton exchange membrane fuel cells. Dr. Minh is internationally known as a leading expert in fuel cell technology and has been invited to give lectures and presentations at numerous technical meetings. Dr. Minh is the co-author of the book Science and Technology of Ceramic Fuel Cells, and over 70 published technical articles on fuel cells and related technologies. Dr. Minh's lecture on the status and applications of fuel cell technology will describe various types of fuel cells and their features, technological status, applications, product development trends, and commercialization prospects.

Raul Quijada (University of Chile) is a Professor of Chemical Engineering at the University of Chile. Prof. Quijada holds a Masters degree in Industrial Chemistry from the Catholic University of Chile and a Ph.D. from the University of Manchester, England. Prof. Quijada will speak on Catalytic Materials and the Environment.

Fabio Ribeiro (Worcester Polytechnic University) is an associate professor of chemical engineering at Worcester Polytechnic University and received his B.S. in chemical engineering in1982 from the Instituto Militar de Engenharia (Brazil), and his M.S. in chemistry in 1984 from the same institution. He was awarded his M.S. and Ph.D. (1989) in chemical engineering from Stanford University. Prof. Ribeiro worked for Professor Gabor A. Somorjai at the Lawrence Berkeley National Laboratory and the University of California at Berkeley from February 1992 to August 1996. His lecture will discuss technological challenges in the areas of hydrogen generation for fuel cell applications, generation of clean energy, and abatement of pollutants.

Martin Schmal (COPPE/UFRJ, Brazil) obtained a degree in chemical engineering in 1964 from the Engineering Catholic University (FEI) in Sao Paulo and his M.S. in 1966 from the Federal University of Rio de Janeiro/COPPE, Brazil. He received his PhD. at the Technische Universität in Berlin, Germany in 1970. Since 1976 he has been a professor at the Federal University of Rio de Janeiro in the chemical engineering department (COPPE/UFRJ). Prof. Schmal has been the head of the Catalysis Nucleus at COPPE/UFRJ since 1985, chairman of the Catalysis Committee at Inst. Bras. Petroleo (Brazil) since 1995 and the head of the chemical engineering program at COPPE/UFRJ since 1997.

Brent H. Shanks (Iowa State University) is an associate Professor of Chemical Engineering. He received his Ph.D. in Chemical Engineering at ChE, California Institute of Technology, 1988. His research interests include Heterogeneous catalysis, alumina mesoporous molecular sieves, new catalytic routes to chemical products from biorenewable feedstocks, and novel process coupling of reactor/catalyst combinations.

Subhash Singhal (Pacific Northwest National Laboratory, PNNL) is a Battelle Fellow and Director of Fuel Cells at the Pacific Northwest National Laboratory. He joined the Energy Science and Technology Division at PNNL after having worked at Siemens Westinghouse Power Corporation for over 29 years. At PNNL, Dr. Singhal is responsible for providing senior technical, managerial, and commercialization leadership to the lab's fuel cell program and the Automotive Commercial Sector outreach activities. He is the recipient of the Orton Memorial Award of the American Ceramics Society for 2001. He holds a B.S. in Physics, Chemistry and Mathematics from Agra University, a B.E. in Metallurgy from the Indian Institute of Science, a Ph.D. in Materials Science and Engineering from the University of Pennsylvania, and an M.B.A. from the University of Pittsburgh.

Susan M. Stagg-Williams (University of Kansas) is an Assistant Professor of Chemical Engineering. She received her Ph.D. in Chemical Engineering from the University of Oklahoma. Her research interests include the Production of Synthesis Gas Utilizing Membrane Reactors and Solid Acid Catalysts as Alternatives for Fine Chemical Production.

Paulo Emilio Valadao de Miranda (COPPE/UFRG, Brazil) is a professor of Metallurgical and Materials Engineering at COPPE/UFRJ (Brazil). He received his M.Sc. and Ph.D. at UFRJ (Brazil) and undertook post-doctoral studies in France at the Université de Paris Sud and at Ecole Centrale de Paris. At COPPE/UFRJ he is the head of the Laboratório de Hidrogênio. He is also the editor of Materia. Prof. V. de Miranda's current research interests include: hydrogen storage materials, fuel cells, hydrogen diffusion barriers, hydrogen sensors, hydrogen embrittlement, and hydrogen production from hydrocarbons using plasma pyrolysis.

Roberto C. Villas Bôas (IMMAC, Brazil) is a professor at Escola Politécnica (USP) in Brazil and professor at La Sapienza, Rome. He is a former professor at the Federal University of Rio de Janeiro. He is currently a principal researcher at Center for Minerals Technology (CETEM/MCT) in Brazil. Prof. Villas Boas is the chairman of the International Materials Assessment and Application Centre (IMAAC/UNIDO) and the International Coordinator of the Programa Iberoamericano de Ciencia y Tecnologia para el Desarrollo (CYTED-XIII). He has edited several books and written many papers on materials technology.

Wayne Worrell (University of Pennsylvania) is Professor of Materials Science and Engineering in the School of Engineering and Applied Science at the University of Pennsylvania. He received his Ph.D. in 1963 from the Massachusetts Institute of Technology. Prof. Worrell's current science and technology interests are in advance solid-oxide-fuel cells. He has published over 110 papers, has 10 patents and has been a consultant and reviewer for more than thirty governmental and industrial laboratories. Prof. Worrell's scientific and technical achievements have been recognized through the Outstanding Achievement Award of the High-Temperature Materials Division of The Electrochemical Society (1988), the Carl Wagner Memorial Award of The Electrochemical Society (1989), the Solid State Science and Technology Award of The Electrochemical Society (1995), and his election as an Honorary Member of The Electrochemical Society (1996).

Miguel Jose-Yacaman (University of Texas at Austin) is a visiting professor of Chemical Engineering. His research focuses on nano and molecular technology. Using cutting-edge electron microscopy and related tools, Dr. Jose-Yacaman is able to describe nano particles and their interactions.

Appendix 6: Program Agenda

Monday, October 20

10:00 Opening Remarks and Introductions
10:30 The Hydrogen Economy: Opportunities of Nanoscience and Nanotechnology to Address some Grand Challenges, *Prof. Mildred S. Dresselhaus, Massachusetts Institute of Technology, U.S.A.*
11:30 Discussion
12:30 Lunch
2:00 Technological Challenges for Petrobras Future as an Energy Company**,** *Dr. Fernando Baratelli Junior, Manager of Gas and Energy of Petrobras R&D (CENPES), Brazil*
3:00 Discussion
3:30 Roundtable Discussions (Students and Lecturers)

Tuesday, October 21

9:00 Solid Oxide Fuel Cells: Fundamentals and Applications, *Dr. S. C. Singhal, Pacific Northwest National Laboratory, U.S.A.*
10:00 Discussion
10:30 Break
11:00 Fuel Cell Technology: Principles and Applications, *Dr. Nguyen Minh, General Electric Hybrid Power Generation Systems, U.S.A.*
12:00 Discussion
12:30 Lunch
2:00 Materials Issues in Environmental Protection: Millennium Science Initiative: Water – a Mineral Approach, *Prof. Virginia S.T. Ciminelli, Federal University of Minas Gerais, Brazil*
3:00 Discussion
3:30 Break
4:00 Hydrogen and Hydride Detection in Materials, *Prof. Paulo Emílio V. de Miranda, Laboratório de Hidrogênio, Coppe, Federal University of Rio de Janeiro, Brazil*
5:00 Discussion
5:30 Roundtable Discussions (Students and Lecturers)

Wednesday, October 22

9:00 Fuel Processing for Fuel Cells, *Prof. John C Amphlett, Royal Military College, Kingston, Canada*
10:00 Discussion
10:30 Break
11:00 Sequential and Simultaneous Electrodeposition of Electrocatalysts on HOPG and Glassy Carbon Substrate for Methanol Oxidation, *Prof. Carlos R. Cabrera, University of Puerto Rico-Río Piedras, San Juan, Puerto Rico*
12:00 Discussion
12:30 Lunch
2:00 Moving Towards The Hydrogen Economy: Internal Combustion Engine To The Fuel Cell, *Dr. Robert J. Farrauto, Engelhard Corporation, U.S.A.*
3:00 Discussion
3:30 Break
4:00 Solid Oxide Fuel Cells (SOFCs) For Direct Utilization of Hydrocarbon Fuels, *Prof. Wayne L. Worrell, University of Pennsylvania, U.S.A.*
5:00 Discussion
5:30 Roundtable Discussions (Students and Lecturers)

Thursday, October 23

9:00 Current Issues on Sustainable Development that Impact the Materials Industries, *Prof. Roberto. C. Villas-Bôas: CYTED-XIII, IMAAC/UNIDO, Brazil*
10:00 Discussion
10:30 Break
11:00 Materials Degradation and Environment, *Ernesto J. Calvo, Universidad de Buenos Aires, Argentina*
12:00 Discussion
12:30 Lunch
2:00 Improving our Environment: Examples from Heterogeneous Catalysis, *Prof. Fabio H. Ribeiro, Purdue University, U.S.A.*
3:00 Discussion
3:30 Break
4:00 Materials for Energy Conversion and Environmental Protection: Scientific Advances and Policy Issues, *Prof. Martin Schmal, COPPE/UFRJ, Brazil*
5:00 Discussion
5:30 Roundtable Discussions (Students and Lecturers)

Friday, October 24

9:00 Group Tour to Petrobras CENPES Laboratory (all day)

Saturday, October 25

9:00 Student Group 1
9:30 Student Group 2
10:00 Student Group 3
10:30 Break
10:45 Student Group 4
11:15 Student Group 5
11:45 Student Group 6
12:15 Break
12:30 Student Group 7
1:00 Student Group 8
1:30 Group lunch and photo

Sunday, October 26

Free Time

Monday, October 27

9:00 Nanostructured Materials Designed for Use in the Catalytic Conversion of Biorenewable Feedstocks, *Prof. Brent H. Shanks, Iowa State University, U.S.A.*
9:30 Syngas Generation using Supported Pt Catalysts, *Dr. Susan M. Stagg-Williams, University of Kansas, U.S.A.*
10:00 Discussion
10:30 Break
11:00 Hydrogen from Catalytic Reforming of Biomass-derived Hydrocarbons in Liquid Water, *Prof. James A. Dumesic, University of Wisconsin, U.S.A.*
11:30 Heterogeneous Catalysis for Conversion of Bio-Based Organic Acids, *Prof. Dennis J. Miller, Michigan State University, U.S.A.*
12:00 Discussion
12:30 Lunch
2:00 Solid Acids and Bases as Environmentally Benign Catalysts for the Production of Chemicals *and* Next Generation Solid Catalysts for the Production of Ammonia, *Prof. Robert J. Davis, University of Virginia, U.S.A.*
3:00 Discussion
3:30 Break

4:00 Polymers and Catalyst Processes Used For Environmental Protection, *Prof. Raúl Quijada, Universidad de Chile and Center for Advanced Interdisciplinary Research in Materials(CIMAT), Santiago, Chile*
5:00 Discussion
5:30 Advanced Catalytic Materials, *Prof. Miguel Jose Yacaman, University of Texas Austin, U.S.A.*
6:30 Discussion

Tuesday, October 28
Brazil- MRS Meeting

Wednesday, October 29
Brazil- MRS Meeting

Appendix 7: Sample Student Research Plan

Pan-American Advanced Studies Institute (PASI) 2003
Rio de Janeiro, Brazil

BLOCK COPOLYMER ASSISTED SELF-ASSEMBLY OF NANOPOROUS $(La_{0.6}Sr_{0.4})(Fe_{0.8}Co_{0.2})O_{3-\delta}$ CATHODES FOR SOFC's

Christopher Chervin
University of California, Davis USA
Dr. Fabio C. Fonseca
Nuclear and Energy Research Institute, Sao Paulo Brazil
Carlos B. W. Garcia
Cornell University, Ithaca USA
Mery C. G. Marroquin
Pontificia Universidade Catolica do Rio de Janeiro, Brazil
Dr. Victor Poblete
Nuclear Energy Chilean Commission, Santiago Chile

Introduction

A fuel cell is an energy conversion device that generates electricity and heat by electrochemically combining a fuel and an oxidizing gas via an ion conducting electrolyte without the need for combustion. The result is much higher energy conversion efficiencies than conventional thermo-mechanical methods. Consequently, fuel cells have much lower carbon dioxide emissions than fossil fuel-based technologies for the same power output. They also produce negligible amounts of SO_X and NO_X, the main constituents of acid rain and photochemical smog.

Among the various types of fuel cells, the solid oxide fuel cell (SOFC) is promising for high-power stationary generation, although research being performed in academia and industry has programs extending the utility of SOFC's to applications ranging from low power residential electricity generation to portable auxillary power units (APUs) in transportation. One of the main advantages of SOFC's is the ability to use conventional fuels, such as natural gas. This eliminates the need for a new fuel infrastructure advancing the possibility of implementation into everyday life, albeit manufacturing costs still need to be addressed. The high power efficiency and low emission aspects of SOFC's make research into this technology an exciting and important area of study.

A single SOFC is a solid state device consisting of two electrodes (anode and cathode) separated by electrolyte. Fuel (usually H_2, CO, or CH_4) arrives at the anode where it reacts with oxygen ions from the electrolyte releasing electrons to the external circuit. On the other side of the fuel cell, oxidant (O_2 or air) is fed to the cathode where it supplies the oxygen ions for the electrolyte by accepting electrons from the external circuit. The electrolyte conducts these ions between the electrodes maintaining overall electrical charge balance. The flow of electrons in the external circuit provides useful power.

Since the fuel cell is not limited by Carnot cycle thermodynamics, the efficiency has been reported to be as high as 80% in some applications where cogeneration of heat and electricity are utilized. In applications where heat is not recovered, the efficiency is between 50-60%. These efficiencies are hindered by Ohmic and overpotential losses inherent in the cell fabrication and the materials used. The most significant loss is the overpotential at the cathode caused by a variety of kinetic factors including low ionic conductivities, gas diffusion, and low reaction surface area. Since this is the area with the greatest potential for improvement, we propose a methodology to decrease the over-potential by using a block copolymer to nanostructure the cathode material.

Several methods have been developed to nanostructure ceramic materials based on self-assembly techniques. Most work in this area is based on silica materials using a sol-gel approaches and templating molecules such as surfactants to generate a lyotropic miscellar phase. Work in this area was first pioneered by researchers in the early 1990's, but since then it was found that non-ionic surfactants based on amphiphilic block copolymers could also be used with the benefit of increasing the pore size of the materials to diameters as large as 20 nm. Amphiphilic copolymers synthesized with even larger molecular weights improved the structuring ability of the polymers to generate even larger pore sizes (>50 nm) with improved long range order and new morphologies. The typical morphology is a hexagonal array of cylindrical pores in a matrix of inorganic, but other morphologies have been found exhibiting cubic bicontinuous structures where the pores extend in three directions. We propose to study the affect of these different pore geometries on the performance of the cathode material.

Today's technology employs several ceramic materials for use as the cathode in SOFC's. Traditionally, the cathode is based on a mixed conducting perovskite, strontium doped lanthanum manganate ($LaMnO_3$). Since this oxide has a low ionic conductivity at operating temperatures, in practice the cathode is mixed with the electrolyte material as a means to reduce the overpotential generating a composite of the two phases. Since it is desired to lower the high operating temperature of SOFC's (usually between 800-1000 °C), other cathode materials have recently been developed with high ionic conductivities at temperatures between 600-700 °C with appreciable electronic conductivity. A good mixed conducting material at these temperatures leads to the possibility of generating a single phase cathode greatly simplifying fabrication. One such material is the doped lanthanum ferrite with the perovskite structure of the following composition: $La_{0.6}Sr_{0.4}Fe_{0.8}Co_{0.2}O_{3-\delta}$ (LSCF).

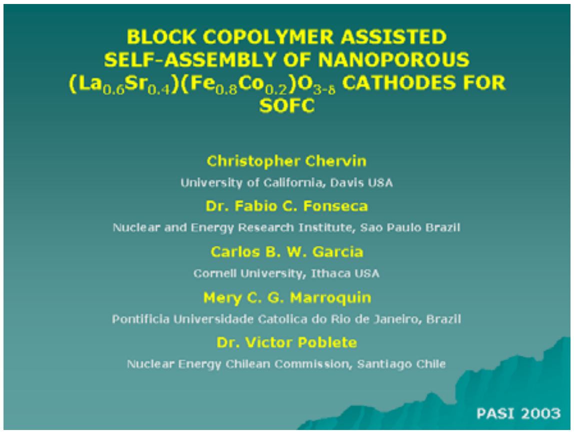
Project

We propose to study the microstructure–performance relationships between a nanoporous LSCF cathode prepared from a self-assembled block copolymer-inorganic composite. The use of a block copolymer to structure the inorganic material for a cathode in a SOFC is new. Mamak, et al, recently showed the possibility of using a surfactant to generate a mesoporous lanthanum strontium manganite/yttria-stabilized zirconia composite, but temperatures above 600 °C lead to a collapse of the pore structure. Mesoporous amorphous aluminosilicates prepared from block copolymers lead to improved thermal stability to temperatures as high 850 °C primarily due to the thicker wall spacing between pores. Crystalline materials prepared in this way should stabilize the pore structure to even higher temperatures since the limitation of a glass transition temperature does not exist.

Block copolymer-inorganic composites will be made by first dissolving the structure directing polymer, poly(isoprene-block-ethylene oxide) PI-b-PEO, in an organic solvent and mixing this with an aqueous solution of the hydroxide salts of the cations in the correct stoichiometric ratio for the LSCF material. Bulk films will be cast leading to a cooperative self assembly between the salts and the block copolymer. Due to the hydrophilic nature of PEO, the salts should segregate to these domains possibly through hydrogen bonding, cation coordination, or both. Upon calcination of the films, the LSCF material will crystallize in the same morphology of the composite film as the polymer is pyrolyzed away. This was observed in the studies using the surfactant as the porogen and should be analogous to the block copolymer system. The calcined material will be ground to form a powder with a small particle size and then sprayed onto the electrolyte as the cathode material. It may also be possible to prepare the cathode by casting the composite film directly onto the electrolyte. Both methodologies will be explored and performance compared. After half-cell fabrication, a battery of electrochemical tests will be performed to determine the overpotential in the nanoporous cathode. These results will be compared to similar materials prepared without pore structure to determine the degree of improvement.

Conclusions

- We propose a new method to produce nanoporous cathodes from block copolymer mesophases for solid oxides fuel cells.
- This new methodology can be extended to the synthesis of other electrodes that required crystalline structure, high porosity, and homogeneity.
- The participation of new undergraduate students is in agreement with the sustainability and projection of our proposition.
- Finally, the interactions between scientists and engineers of different countries will play an important role toward the success of this project and benefit the international community.


BLOCK COPOLYMER ASSISTED SELF-ASSEMBLY OF NANOPOROUS $(La_{0.6}Sr_{0.4})(Fe_{0.8}Co_{0.2})O_{3-\delta}$ CATHODES FOR SOFC
Christopher Chervin
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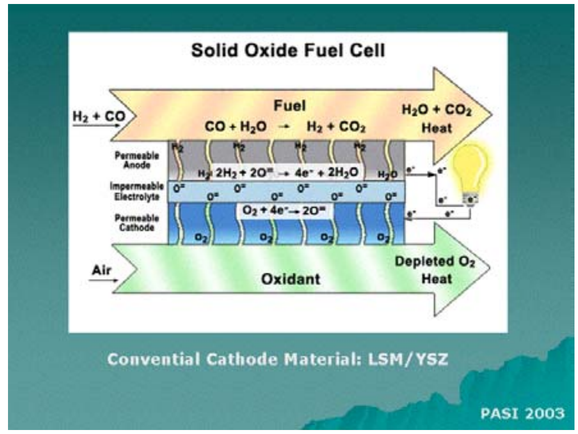
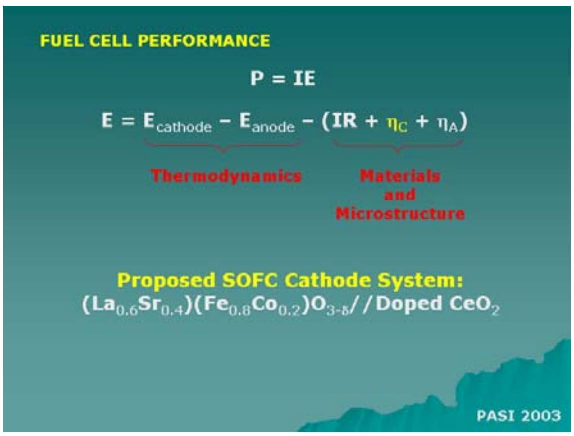
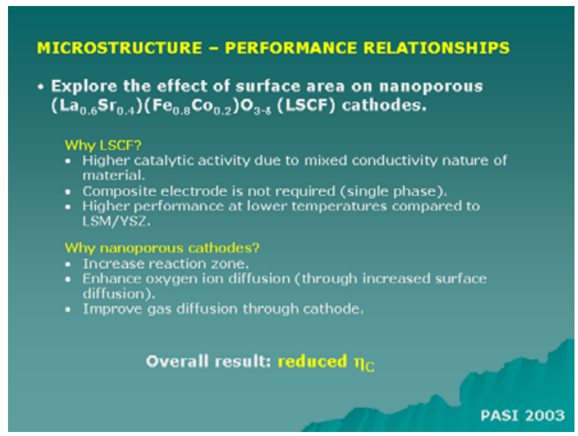
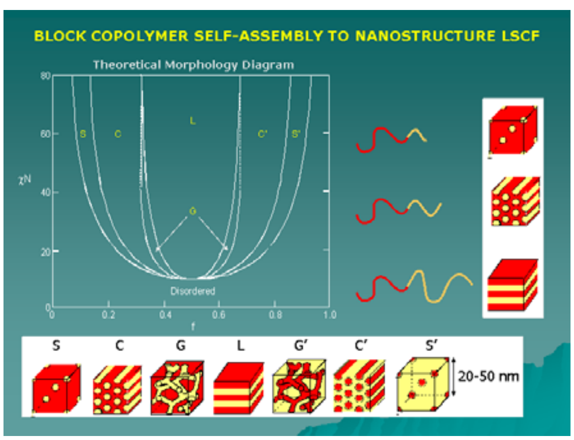
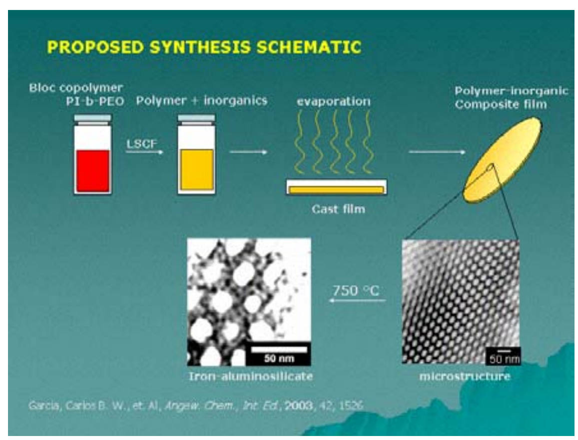
Pontificia Universidade Catolica do Rio de Janeiro, Brazil
Dr. Victor Poblete
Nuclear Energy Chilean Commission, Santiago Chile
PASI 2003

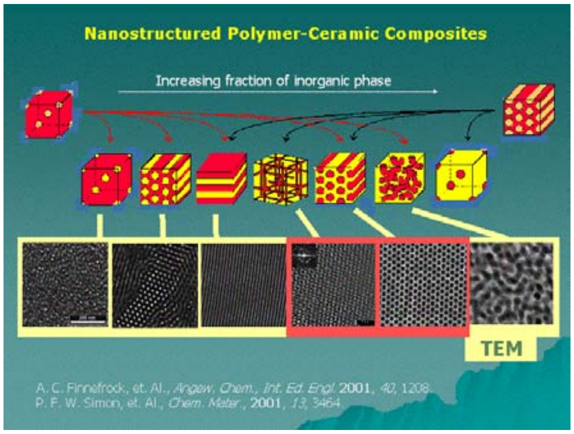

Solid Oxide Fuel Cell
$H_2 + CO$
Fuel
$CO + H_2O \rightarrow H_2 + CO_2$
$H_2O + CO_2$
Heat
Permeable Anode
Impermeable Electrolyte
Permeable Cathode
$2H_2 + 2O^= \rightarrow 4e^- + 2H_2O$
$O_2 + 4e^- \rightarrow 2O^=$
Air
Oxidant
Depleted O_2
Heat
Convential Cathode Material: LSM/YSZ
PASI 2003

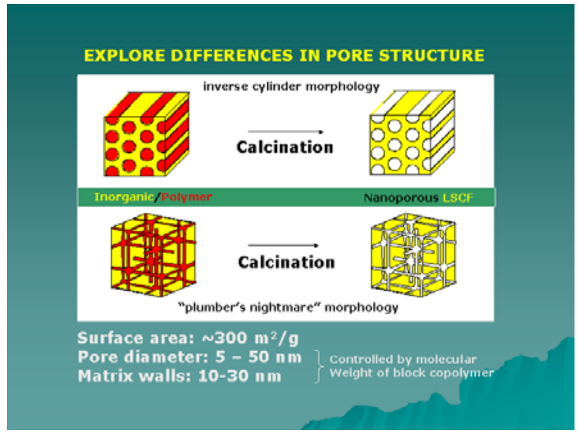

FUEL CELL PERFORMANCE
$P = IE$
$E = E_{cathode} - E_{anode} - (IR + \eta_C + \eta_A)$
Thermodynamics
Materials and Microstructure
Proposed SOFC Cathode System:
$(La_{0.6}Sr_{0.4})(Fe_{0.8}Co_{0.2})O_{3-\delta}$//Doped CeO_2
PASI 2003

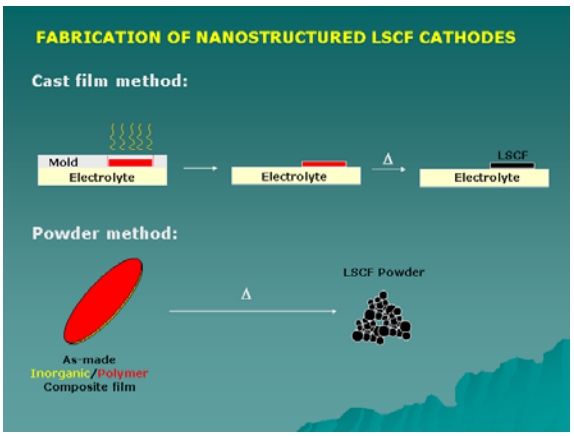

MICROSTRUCTURE – PERFORMANCE RELATIONSHIPS
• Explore the effect of surface area on nanoporous $(La_{0.6}Sr_{0.4})(Fe_{0.8}Co_{0.2})O_{3-\delta}$ (LSCF) cathodes.
Why LSCF?
• Higher catalytic activity due to mixed conductivity nature of material.
• Composite electrode is not required (single phase).
• Higher performance at lower temperatures compared to LSM/YSZ.
Why nanoporous cathodes?
• Increase reaction zone.
• Enhance oxygen ion diffusion (through increased surface diffusion).
• Improve gas diffusion through cathode.
Overall result: reduced η_C
PASI 2003

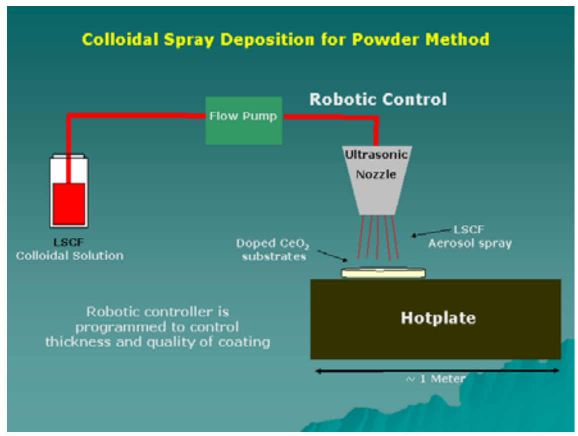

BLOCK COPOLYMER SELF-ASSEMBLY TO NANOSTRUCTURE LSCF
Theoretical Morphology Diagram
χN
f
Disordered
S C G L G' C' S'
20-50 nm

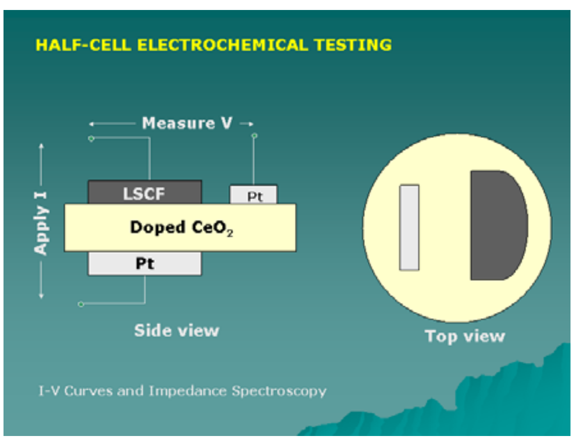

PROPOSED SYNTHESIS SCHEMATIC
Bloc copolymer PI-b-PEO
Polymer + inorganics
LSCF
evaporation
Cast film
Polymer-inorganic Composite film
750 °C
50 nm
Iron-aluminosilicate
microstructure
Garcia, Carlos B. W., et. Al, Angew. Chem., Int. Ed, 2003, 42, 1526

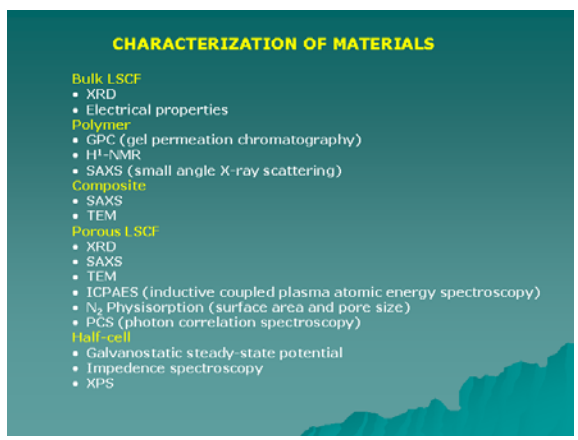

Nanostructured Polymer-Ceramic Composites
Increasing fraction of inorganic phase
TEM
A. C. Finnefrock, et. Al., Angew. Chem., Int. Ed. Engl. 2001, 40, 1208
P. F. W. Simon, et. Al., Chem. Mater., 2001, 13, 3464


EXPLORE DIFFERENCES IN PORE STRUCTURE
inverse cylinder morphology
Calcination
Inorganic/Polymer
Nanoporous LSCF
Calcination
"plumber's nightmare" morphology
Surface area: ~300 m²/g
Pore diameter: 5 – 50 nm
Matrix walls: 10-30 nm
Controlled by molecular
Weight of block copolymer


FABRICATION OF NANOSTRUCTURED LSCF CATHODES
Cast film method:
Mold
Electrolyte
Electrolyte
Δ
LSCF
Electrolyte
Powder method:
Δ
LSCF Powder
As-made
Inorganic/Polymer
Composite film


Colloidal Spray Deposition for Powder Method
Flow Pump
Robotic Control
Ultrasonic
Nozzle
LSCF
Colloidal Solution
Doped CeO₂
substrates
LSCF
Aerosol spray
Robotic controller is
programmed to control
thickness and quality of coating
Hotplate
~ 1 Meter


HALF-CELL ELECTROCHEMICAL TESTING
Measure V
Apply I
LSCF
Pt
Doped CeO₂
Pt
Side view
Top view
I-V Curves and Impedance Spectroscopy


CHARACTERIZATION OF MATERIALS
Bulk LSCF
• XRD
• Electrical properties
Polymer
• GPC (gel permeation chromatography)
• H¹-NMR
• SAXS (small angle X-ray scattering)
Composite
• SAXS
• TEM
Porous LSCF
• XRD
• SAXS
• TEM
• ICPAES (inductive coupled plasma atomic energy spectroscopy)
• N₂ Physisorption (surface area and pore size)
• PCS (photon correlation spectroscopy)
Half-cell
• Galvanostatic steady-state potential
• Impedence spectroscopy
• XPS

UNIQUENESS OF TEAM

1. Multidisciplinary

- Solid-State Chemistry
- Physics
- Materials Science and Engineering
- Polymer Science and Chemistry

2. Geographically Diverse

- Chile
- USA
- Brazil
- Peru

3. Broad Technological Knowledge

- Polymer synthesis
- Materials fabrication
- Materials characterization

TEAM SPECIALTY AND WORK STRATEGY

Victor Poblete: Materials Scientist and Engineer
- Bulk LSCF characterization
- Surface chemistry and characterization (XPS)

Carlos B. W. Garcia: Materials/Polymer Scientist and Engineer
- Block copolymer synthesis and LSCF composite preparation
- SAXS, TEM

Mery C. G. Marroquin: Materials Scientist and Engineer
- Microscopy of materials (Optical and SEM)

Christopher Chervin: Solid State Chemist
- Half-cell fabrication
- Electrochemical characterization

Fabio Fonseca: Physicist
- Surface area analysis
- Particle size distribution characterization
- Electrochemical characterization

PROJECT COSTS

Net US $ per year

Details	Cornell	UC Davis	Brazil	Perú	Chile	Total
Chemicals	2,000	3,000	1,500	0	2,000	8,500
Travel	2,000	2,000	2,000	2,000	2,000	10,000
Charact.	3,000	0	1,000	2,000	3,000	9,000
Other	1,000	1,000	1,000	1,000	1,500	5,500
Student honorary	0	0	0	0	10,000	10,000
Total	8,000	6,000	4,500	5,000	18,500	US $43,000

Project Length: 2 years
Total Cost: $86,000

ACKNOWLEDGEMENTS

- **PASI**
- **Prof. Chang and Jennifer Moncel**
- **Lecturers**
- **All the participants**

Ps- we need jobs.

Appendix 8: Evaluation Forms

PASI 2003 **Student Evaluation Form** **Page 1 of 3**

1. The structure of the PASI (lectures, Q&A, roundtable discussions, meals and free time) was conducive to information exchange and research collaborations.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments: (Please also comment on the individual components)

   ____
   ____
   ____
   ____
   ____
   ____

2. The PASI allowed me to have valuable cultural interactions with lecturers and my peers.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments:

   ____
   ____
   ____
   ____
   ____
   ____

3. The technical content at the PASI will help my research.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments:

   ____
   ____
   ____
   ____
   ____
   ____

4. The PASI was a useful international networking experience.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments:

   ____
   ____
   ____
   ____
   ____
   ____

5. The PASI gave me valuable experience in international team building.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments:

6. Pre-event communication with my team members was useful to project development.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments:

7. I plan to continue the research collaborations that I started at this PASI.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments:

8. The PASI coordinator kept me well informed regarding PASI preparations, structure and goals.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments:

9. The lecturers were well-selected for this event.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments:

10. What did you appreciate most about this event?

11. What did you like least?

12. What are your suggestions for improvement?

1. The structure of the PASI (lectures, Q&A, roundtable discussions, meals and free time) was conducive to information exchange and research collaborations.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments: (Please also comment on the individual components)

2. The PASI allowed me to have valuable cultural interactions with students and colleagues.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments: (Please also comment on the individual components)

3. The technical content at the PASI will help my research.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments: (Please also comment on the individual components)

4. The PASI was a useful international networking experience.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments: (Please also comment on the individual components)

5. This event was effective in promoting networking and research collaborations among young Pan-American scientists.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments: (Please also comment on the individual components)

6. The PASI coordinator kept me well informed regarding PASI preparations, structure and goals.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments: (Please also comment on the individual components)

7. The students were well-selected for this event.

   Strongly Agree Agree Neutral Disagree Strongly Disagree

   Comments: (Please also comment on the individual components)

8. What was your impression of student participation?

9. What did you appreciate most about this event?

10. What did you like least?

11. What are your suggestions for improvement?

Appendix 9: Program Overview in Pictures

Keynote speaker Prof. Mildred S. Dresselhaus of MIT opens the PASI with a talk on the Hydrogen Economy

Dr. Farrauto of Engelhard Corporation discusses fuel cells from an industrial point of view.

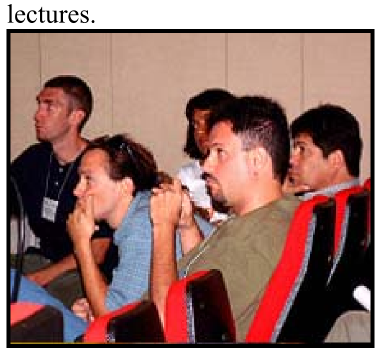
Prof. Villas Boas of IMMAC UNIDO adds environmental policy perspective to the technical program

Prof. G. Solorzano of Brazil and Prof. J. Amphlett of Canada mentor student groups during roundtable discussions

Raed Hashaikeh of Canada and Daniel Zanetti del Florio of Brazil exchange project ideas between lectures.

Another afternoon of roundtable discussions- Team 3 consults with Prof V. de Miranda of Brazil

Jackeline Quinones of Venezuela presents part of her team's research plan for the PASI audience



Team 4 listens intently to another student research plan.

Team 2: Maria Curet Arana (US), Kevin Krantz (US), Ian Wheeldon (Canada), Juliano Toniolo (Brazil), and PG Beerman (Panama)

Appendix 10: PASI Group Photos

Team 1: V. Lavayen (Chile), J. Bravo (US), R. Hendershot (US), A. Martinez (Mexico), J. Quinones (Venezuela)

Team 3: F. Gracia (US), M. Vasquez (US), C. Neyertz (Argentina) K. Wain (US), C. Magana (Mexico)

Team 4: C. Chervin (US), V. Poblete (Chile), M. Gomez Marroquin (Peru), F. Fonseca (Brazil), C. Garcia (US)

Team 5: F. Prado (Argentina), W. Francillon (US), B. Rauch (US), S. Jesse (US) Not Shown: P. Dias (Brazil)

Team 6: C. Gutierrez Wing (Mexico), P. Villalobos (Brazil), P. Matter (US) Not shown: O. Roshdy (US) and J. Kenney (US)

Team 7: R. Hashaikeh (Canada), F. Castro (Argentina), D. Zanetti del Florio (Brazil), C. Arvin (US), M. Alvarez (Chile)

Team 8: F. Lineo (Chile), M.J. Berrocal (Peru), R. O'Hayre (US) K. Hurysz (US), G. Huber (US)

Drs. Amphlett, Chang, Singhal and Minh

PASI Group Photo